

RESEARCH ARTICLE

Impacts of the Victoria Nile Bujagali hydropower dam on fisheries and livelihoods

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Abstract

The Upper Victoria Nile (UVN) flows from Lake Victoria into Lake Kyoga, spanning 117 km and supports a diverse aquatic fauna that sustains livelihoods of riverside communities. The UVN is habitat to critically endangered (*Labeo victorianus*), near threatened (*Oreochromis variabilis* and *Oreochromis esculentus*), and rare species (*Neochromis simotes*). Four hydropower dams were built on the UVN to provide energy for industrial and socioeconomic development, notwithstanding consequential environmental and socioeconomic impacts. The impacts of Bujagali hydropower (BHP) dam on fisheries and livelihoods were assessed biannually (April and September) from 2006 to 2019, using fishing effort, species abundance, catch composition, and economic beach revenue at upstream, mid-reservoir, and downstream transects. The fishing boats increased from 31 in 2009 to 293 in 2019 and fishers from 83 to 500 over the monitoring period. Maximum annual catch of 461.4 t was recorded in 2014 and lowest of 54.2 t in 2009. In all transects, *Protopterus aethiopicus* and *Labeo victorianus* were least in the commercial catches and the use of *Mormyrus kannume* juveniles as bait for Nile perch fishery corresponded with increased catches from 3.3 t in 2009 to 148.2 t in 2019. Women were mostly engaged in post-harvest activities such as fish drying, smoking, and food vending. These observations suggest coupling effects of the hydropower dam and ineffective fisheries management. The harvest of *M. kannume* wild stocks for bait should be banned and research in possible domestication of the species undertaken. There is a need to strengthen fisheries enforcement to curb illegal effort and overexploitation and to implement conservation actions to mitigate potential biodiversity impacts from the hydropower dam operations.

KEYWORDS

biodiversity conservation, fisheries management, *Neochromis simotes*, overexploitation, Upper Victoria Nile

1 | INTRODUCTION

Rivers are among the world's most important ecosystems sustaining biodiversity and providing countless services including some of the largest fisheries globally (Thieme et al., 2021). However, other

socioeconomic uses of rivers often underestimate the basis for sustaining the diverse ecosystem service that rivers provide. For example, fish populations are highly dependent upon the characteristics of their aquatic habitat, which supports all their biological functions (Hoeinghaus et al., 2009).

Habitat characteristics that ultimately influence fisheries sustainability range from river flow to rocky and soft bottom conditions and water quality. Studies in the Amazon, Mekong, and Congo River basins have shown that hydropower development represents a major threat to fish biodiversity and the maintenance of critically important fisheries worldwide (Vörösmarty et al., 2010; Winemiller et al., 2016), with potential to damage food security and rural livelihoods in tropical regions (Pringle, Freeman, & Freeman, 2000; Ziv, Baran, Nam, Rodríguez-Iturbe, & Levin, 2012). The threats to the rivers' ecosystem services could be attributed to changes in habitat characteristics. Negative impacts of hydropower dams can also be manifested in observable changes in functional traits of the fishes such as fish body size, reproduction, food preferences, habitat use, and metabolism (Arantes, Fitzgerald, Hoeinghaus, & Winemiller, 2019).

Hydroelectric dams also impact the spatiotemporal patterns of fish community structure and fisheries production by obstructing migration routes, altering sediment transport and water quality, promoting invasions by alien species and biotic homogenization, and favoring generalist over specialist species (Araújo et al., 2013; Barthem, de Brito Ribeiro, & Petrere, 1991; Forsberg et al., 2017). These effects stem from having the entire life cycle of the potamodromous species occurring within fresh waters of a river system (Northcote, 1998). Fish reproduction and feeding zones may be separated by distances that may vary from a few meters to hundreds of kilometers. Moreover, large-scale hydroelectric projects are also associated with road construction, deforestation and urban development, and sewage disposal in surrounding regions (da Silva Junior, dos Santos, Szlafsztein, Gomez, & Pereira, 2018; Stickler et al., 2013), which may act synergistically with altered flow regimes to impact aquatic ecosystem health and therefore biodiversity and production. Dams cause significant direct loss of fish in turbines or spillways during migration but also lead to habitat loss, discharge modifications, water quality and temperature changes, and increased predation pressure; (Jellyman & Harding, 2012; Marmulla, 2001; Rytwinski et al., 2017).

In Africa, the negative ecological effects of dams have been reported on rivers Zambezi (Arthur et al., 2017), Tana in Kenya (Hughes, 1984), Aswa in Egypt (White, 1988), and Senegal in West Africa (Adams, 1985; Hughes, 1984). Despite the negative impacts of dam construction, socio economic benefits such as industrial growth, urbanization, and employment arising from supply of hydro-energy have accrued to the communities in the East African region (R J Burnside International Limited, 2006; The World Bank, 2018). For example, the 117-km-long Upper Victoria Nile (UVN) in Uganda has witnessed some sites being developed for hydropower generation. However, this part of the River Nile that flows northwards from Lake Victoria through Lake Kyoga northwards to Lake Albert and ultimately to the Mediterranean sea is known for harboring endemic species as well as supporting the livelihoods of riparian communities with several exploited endemic and alien species including *Lates niloticus*, *Oreochromis niloticus*, *Rastrineobola argentea*, *Labeo barbus altianalis*, *Labeo victorianus*, and *Mormyrus kanume* (Bassa et al., 2020; Nelson et al., 2013; Witte et al., 1992). Some studies have observed that the UVN is the faunal refugia to critically endangered fish species such as *L. victorianus* (Chapman, Chapman, Kaufman, Witte, & Balirwa, 2008; NaFIRRI, 2017) and is habitat to a rare

haplochromine species, *Neochromis simotes* (Chapman et al., 1996; Greenwood, 1976; Ogutu-Ohwayo, 1988; Wilmsen & Van Hulten, 2017; Witte et al., 1992; Witte et al., 2008). Besides providing fisheries resources, the UVN is a major source of water for domestic industrial use, irrigation and electricity generation (NAPE, 2007).

In order to augment available electricity in Uganda, the 250 MW Bujagali hydropower dam was commissioned in 2012. In view of the reported impacts of hydropower dams, we undertook biannual ecological monitoring of the UVN upstream and downstream of the Bujagali hydropower dam from 2009 up to 2019 with the main objective of understanding the likely ecological and socioeconomic impacts of the dam activities on the fisheries and livelihoods in the affected area.

2 | MATERIALS AND METHODS

2.1 | Description of study area

Bujagali hydropower dam is located downstream of two previously (1954 and 2003) constructed dams (Figure 1). The Bujagali dam construction started in 2007 and was commissioned in 2012. The Bujagali dam (reservoir) is approximately 388 ha in surface area comprising of the then 308 ha surface area of the Victoria Nile, and 80 ha of newly inundated land that is comparatively small as the reservoir water is contained within the steeply incised banks of the river. The reservoir has a maximum depth of 30 m with a mean depth of 9.3 m. This hydropower dam has a residence time of 16 hr and the reservoir's daily fluctuation of between 2 and 2.5 m. The project site is in a zone characterized by a long-wet season (February–May), a short-dry season (June–July), a short-wet season (August–October), and a long-dry season (November–January).

2.2 | Sampling design

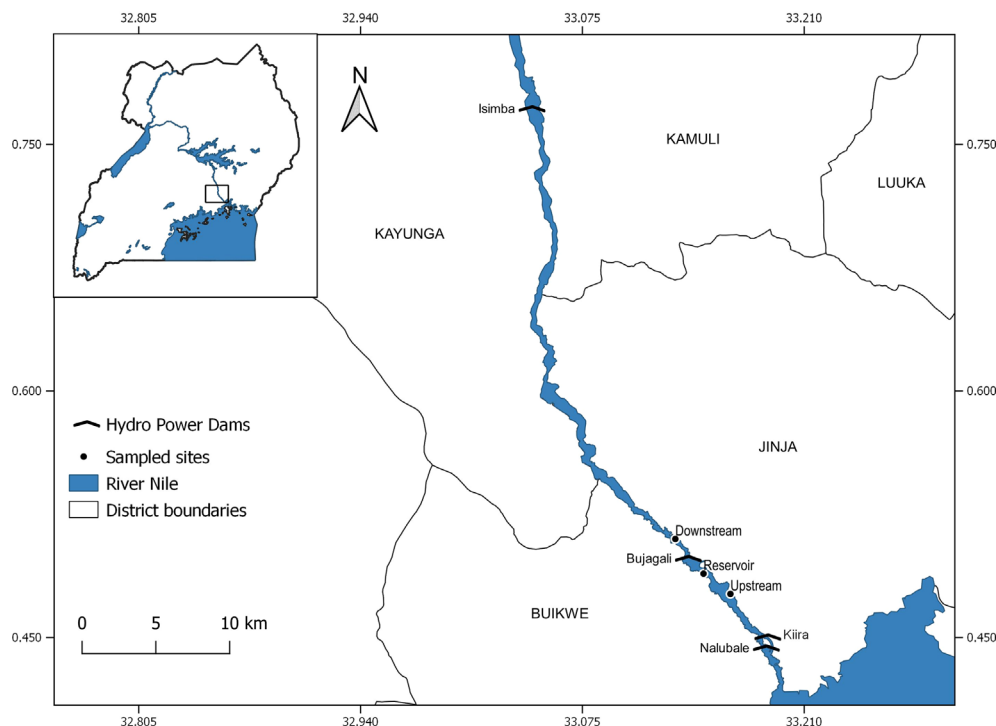
Three transects that is, one upstream (Kalange-Makwanzi), a second in the middle of the reservoir (mid-reservoir), and the third about three kilometers downstream (Buyala-Kikubamutwe) were established as bases for sampling fish populations and livelihoods along the UVN (Figure 1). The mid-reservoir transect was created after dam construction, hence there are no records for catch, revenue, and fishing effort at the mid-reservoir between 2009 and 2011. A longitudinal sampling design (Farrington, 1991) was employed in the study, whereby data were collected biannually (April and September every year) at the three transects between 2006 and 2019.

2.3 | Data collection methods

2.3.1 | Catch and fishing effort data

These data were generated through Catch Assessment Surveys (CASs) and Frame Surveys (FSs) respectively, following Standard Operating Procedures for conducting CASs (LVFO, 2005) and FSs (LVFO, 2014).

FIGURE 1 Map of the study area showing the sampled transects and constructed dams along the Upper Victoria Nile section of River Nile (inset is the location map of Bujagali in Uganda) [Color figure can be viewed at wileyonlinelibrary.com]



Frame Survey, the complete count of all fishing effort variables (i.e., number of fishing crafts by type, number of fishing gears by type and size, and number of fishers) at landing site, was implemented once at all study transects during each monitoring period. At each transect, information on fishing effort variables in every fishing boat was obtained from fishers and/or boat owners.

CASs involve the measurement and recording of fish catch variables such as quantity (weight) and value (price) of catch landed in each sampled boat by species, the type, number, and size of fishing gear used to catch the fish, the fishing duration per night, and the active fishing days per week. At each study transect, catch from all fishing boats that went fishing on the sampling day was recorded. Data were collected for two consecutive days at each transect, to reduce biases in catch estimation arising from nonfishing days due to bad weather and other social factors. For each boat sampled, the catch landed was sorted and identified to species level, the total weight (kg) of each species measured, and price per kilogram of each species was recorded in Uganda shillings and converted to United States dollars using the prevailing exchange rates (1 US\$ = 3,672 UGX) (<https://www.bou.or.ug/bou/bouwebsite/ExchangeRates>). Data generated through CASs were used to calculate the catch per unit effort (CPUE), total catch (C), mean price per kilogram of each landed species, and total economic value of catch at beach level.

2.3.2 | Community livelihoods data

Data on community livelihoods such as number of people employed by the different fishery jobs, by gender category was

generated through Focused Group Discussions and Key Informant Interviews (Mishra, 2016), using structured questionnaires.

2.4 | Data analysis

Data analysis was performed in R.4.0.2 (R Core Team, 2021). The Shapiro–Wilk test was performed to ascertain whether data were normally distributed. Then Kruskal–Wallis (one-way ANOVA) was undertaken on ranks to determine whether there were significant differences in the median catches among the fish species. We used Wilcoxon test to determine whether there were significant differences in the unit prices over the sampled months during the study period. To examine the relationship between price over time using Spearman rank correlation coefficient, we converted the years into dummy variables in ascending order from 2019 (1) to 2019 (13). Similarly, we used the Spearman rank correlation coefficient to examine the relationship between annual catch and beach value over time.

Species presence was denoted by a score of 1 if it was recorded once during each study year and by 2 if its presence was noted twice in each year, while species total absence in a year was designated by 0. The total catch for each fish species landed at each transect was calculated by multiplying the average CPUE by the number of fishing boats by the total number of active fishing days in the sampled month. The corresponding revenue of catch for every species recorded at each transect was determined by multiplying its total monthly weight by the average unit price.

3 | RESULTS

3.1 | Fishing effort indicators

Three major fishing effort indicators were identified at all transects during the study period, they included: fishing boats, fishers, and fishing gears (gillnets, longline hooks, handline hooks, small seines, cast nets, and basket traps). Overall, the majority of fishing effort indicators (boats, fishers, longline hooks, and basket traps) substantially increased over the study period, with peaks observed between 2012 and 2019 (Figure 2). For example, the number of fishing boats increased from 100 in the year 2009 to 293 in 2019, and the number of fishers increased tenfold from 50 to >500 over the same period. Longline hooks were the most dominant fishing gear at the study area (Figure 2). The highest number of gillnets were recorded in 2014 at both upstream and downstream transects, and thereafter gradually decreased. From 2014 to 2019, the highest number of scoop nets per boat was registered at the mid-reservoir ranging from 1 to 15. The absence of fishing effort records at the mid-reservoir between 2009 and 2011 (S1) is because it was not in existence until after completion of dam construction in 2012.

3.2 | Catch species composition

Fifteen fish species (Table 1, Plate 1) were recorded in the commercial catch from all transects for the entire study period, of which six species (*Lates niloticus*, *O. niloticus*, *B. docmak*, *O. variabilis*, *M. kannume*, and *Labeobarbus altianalis*) featured throughout the study period. Over the entire study period, the number of fish species recorded at each site (species richness) was highest at upstream (42.63%), followed by downstream (33.8%), and the least was at the mid-reservoir (23.6%). *Rastrineobola argentea*, also commonly known as mukene in Uganda,

dagaa in Tanzania, and omena in Kenya was prominent at the reservoir in the later years.

3.3 | Annual catch and beach revenue for the selected commercial fish species

The annual catch and revenue of catch at beach level were determined for seven selected commercial fish species (Figure 3), which contributed >1% to the total landings. Annual catch and revenue of fish species varied over sampled years, with two major peaks recorded in 2014 and 2019. The catch and beach revenue were dominated by *Mormyrus kannume* during the two major peaks while the least common was *Oreochromis variabilis* (Figure 3). The median catch was significantly different among the selected fish species (Kruskal-Wallis chi-squared $\chi^2 = 109.77$, $df = 6$, p -value <.001) over the study period. Multiple comparisons with post hoc Dunn test between the species indicated the median catches were significantly different except between *M. kannume* and *Lates niloticus* ($p = .4663$), *Labeobarbus altianalis* and *O. variabilis* ($p = .1663$), and *L. altianalis* and *C. gariepinus* ($p = .0485$).

3.4 | Prices of fish species (mean price per unit weight)

The different fish species fetched various price per unit weight (kilogram) (Figure 4), with prices generally increasing over time. However, there was no significant difference in the unit price per kilogram of fish species between April and September ($W = 1721.5$, $DF = 1$, p -value = .2559). Also, there was a significant positive correlation between the average unit price and sampling season over years (Figure 4). However, there was no significant correlation between the

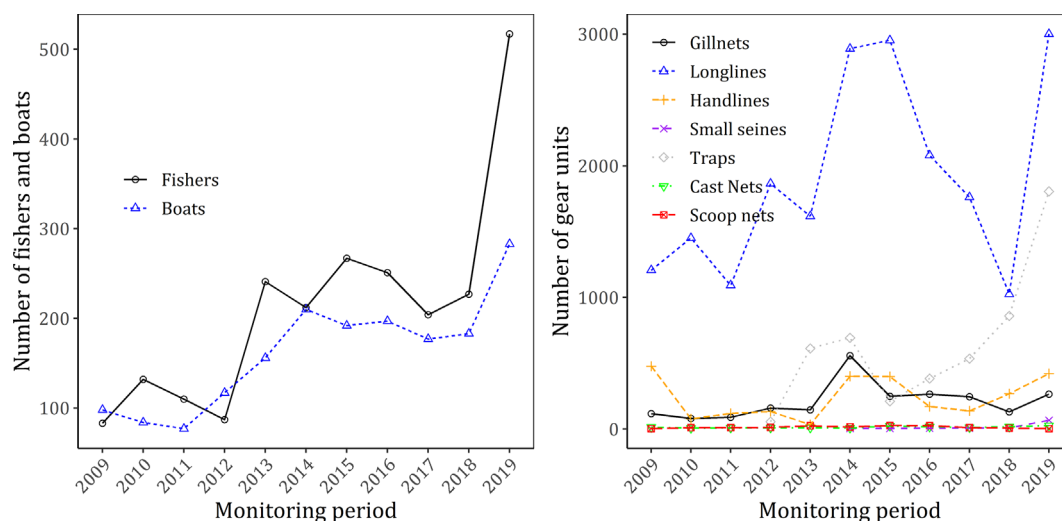


FIGURE 2 Changes in fishing effort indicators (fishers, boats, and fishing gears) at the study transects on UVN for the period 2009–2019 [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

TABLE 1 Fish species recovered in commercial catches at the three study transects before, during, and after Bujagali Hydropower dam construction (US = Upstream, RS = Reservoir, and DS = Downstream)

Monitoring period																
Fish species	Transect	Pre- 2006	Dam construction			Post-dam construction										
			2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Bagrus docmak	US	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	RS	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2	2	2	2
	DS	2	2	2	2	2	2	2	2	1	2	2	1	2	2	2
Lates niloticus	US	2	0	0	0	2	2	2	2	2	2	2	2	2	2	2
	RS	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2	2	2	2
	DS	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2
Oreochromis niloticus	US	2	0	0	2	2	2	2	2	2	1	2	2	2	1	2
	RS	NA	NA	NA	NA	NA	NA	2	1	2	2	1	2	2	2	2
	DS	2	2	2	2	1	2	2	2	2	1	2	0	0	0	1
Oreochromis leucostictus	US	1	0	0	1	1	0	0	0	0	2	2	0	0	0	0
	RS	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0
	DS	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oreochromis variabilis	US	1			2	2	2	2	2	2	2	2	1	2	0	1
	RS	NA	NA	NA	NA	NA	NA	2	0	1	1	0	1	0	0	0
	DS	1			1	2	1	2	1	0	0	0	0	0	0	0
Coptodon zillii	US	2	2	2	2	2	2	2	1	2	2	2	0	1	2	2
	RS	NA	NA	NA	0	0	0	2	0	2	1	0	0	1	0	0
	DS	2	2	0	1	2	2	0	0	0	2	0	0	1	0	1
Haplochromine species	US	1	1	0	2	2	2	2	2	0	1	0	2	2	0	2
	RS	NA	NA	NA	NA	NA	NA	0	NA	0	0	1	1	0	0	0
	DS	2	2	2	1	1	1	2	2	0	1	2	0	1	1	1
Clarias gariepinus	US	1	2	2	2	2	1	1	2	2	2	2	0	0	0	1
	RS	NA	NA	NA	NA	NA	NA	NA	NA	1	0	0	1	2	0	0
	DS	1	2	2	2	2	2	2	2	2	0	1	0	0	0	0
Labeobarbus altianalis	US	2	2	2	2	2	2	2	2	2	2	1	0	1	0	0
	RS	NA	NA	AN	NA	NA	NA	2	NA	2	1	1	0	0	1	0
	DS	2	2	2	0	0	0	2	0	2	0	1	0	1	0	1
Rastrineobola argentea	US	1	0	0	0	2	2	1	1	2	1	0	1	0	0	1
	RS	NA	NA	NA	NA	NA	NA	2	NA	1	1	1	2	1	2	1
	DS	1	2	2	1	1	1	1	1	0	0	0	0	0	0	0
Labeo victorianus	US	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	RS	NA	NA	NA	NA	NA	NA	0	NA	0	0	0	0	0	0	0
	DS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

(Continues)

TABLE 1 (Continued)

Monitoring period															
Fish species	Transect	Pre-2006	Dam construction					Post-dam construction							
			2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Protopterus aethiopicus	US	1	1	0	0	0	0	0	1	1	1	0	0	0	0
	RS	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0
	DS	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Synodontis afrofisheri	US	2	2	2	2	2	1	1	1	0	2	2	2	1	2
	RS	2	NA	NA	NA	NA	NA	NA	1	1	2	1	1	2	1
	DS	2	0	0	0	1	0	0	0	1	2	1	1	1	1
Synodontis victoriae	US	2	0	0	0	0	0	0	0	0	1	0	1	1	0
	RS	NA	NA	NA	NA	NA	NA	NA	0	0	1	1	1	1	0
	DS	1	0	0	0	0	0	0	0	0	1	0	0	0	0
Mormyrus kannume	US	2	2	2	2	2	2	2	2	2	2	2	2	1	2
	RS	NA	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2	2
	DS	2	2	2	2	2	2	2	1	2	2	2	2	2	2

Note: 0 = absence of species, 1 = species recovered once in each monitoring year and 2 = species recovered twice in each monitoring year, NA = not applicable as the reservoir was created in 2012.

unit prices for *C. gariepinus*, *B. docmak*, and *O. variabilis* over the years (Figure 4).

3.5 | Total annual catch and beach revenue of catch at the three study transects on UVN

Annual catch and revenue increased at the three study transects between 2009 and 2019 (Figure 5). As observed in the annual species catch and revenue trends, the major peaks of the total annual catch and revenue occurred in 2014 and 2019 at the study transects (Figure 5). In 2014, 950 t worth US \$ 1.5 million was recorded while in 2019, 910 t valued at US\$ \$ 2.5 million was registered for the three transects. The highest annual catch was recorded at upstream during 2014 and 2019 peaks, followed by the mid-reservoir and the least were registered at downstream transect (Kruskal-Wallis chi-squared $\chi^2 = 22.62$, $DF = 2$, $p < 0.001$). The annual catch and revenue slightly fluctuated at all the transects between 2009 and 2013, before registering a sharp increase in 2014. In 2015, the values drastically declined and fluctuated minimally until 2018 before registering another sharp increase in 2019 (Figure 5). While the mid-reservoir transect was only created after dam construction in 2012, it is worth noting that its creation resulted in drastic increase in catch landings and beach revenue of catch in 2014.

Annual catch and revenue were strongly correlated across the three transects on the Upper Victoria Nile, for downstream ($R = 0.71$, $p < .001$), mid-reservoir ($R = 0.60$, $p < .001$) and upstream (Figure 5). The correlation analysis showed a significant positive relationship between annual catch and revenue ($S = 503,840$, p -value $< .001$, $R = 0.71$).

3.6 | Jobs related to fisheries involving riverside communities

The riverside communities along the UVN derived their livelihoods from four major fisheries related jobs (Figure 6, Plate 2); fishing, fish marketing, boat construction and fishing gear repairing, and food vending. Generally, the number of people engaged in fishery-related jobs increased over the study period, the highest increase was registered between 2013 and 2019. Fishing engaged majority of people who were involved in fishing at the study transects as fishers, followed by fish processing and marketing (Fish Traders and Processors), and food vending (Food vendors) employed the least number of people (Figure 6).

The gender roles in the fisheries were distinct, with women dominating the post-harvest handling and marketing activities, while the men dominated the fishing and boat construction job categories (Figure 6, Figure S3). All boat builders and net repairers recorded on the UVN were men. The female fishers constituted $<2\%$ for the years they were encountered (Figure 6, Figure S3). Food vending at landing sites mostly engaged women, except during 2010, 2012, and 2018, where the number of men involved in food vending was higher than

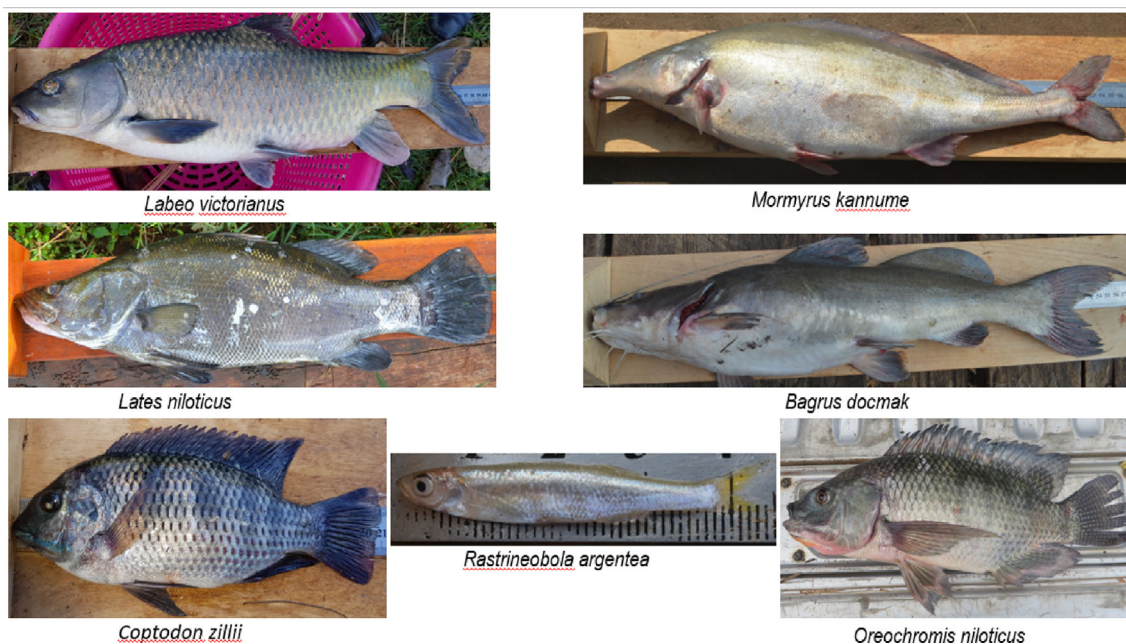


PLATE 1 Common fish species landed at the study transects on UVN (2009–2019) [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

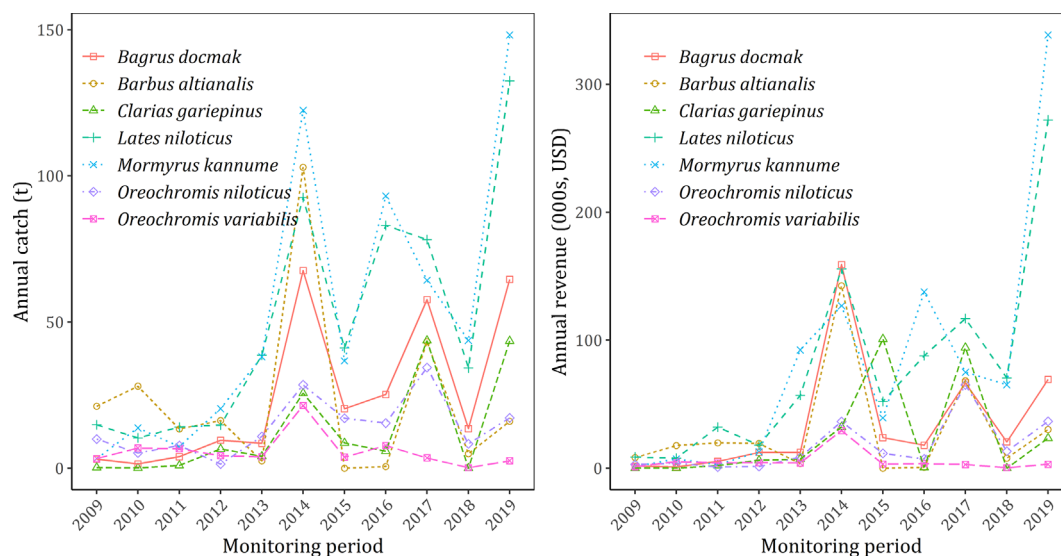


FIGURE 3 Changes in annual fish catch and revenue of catch at beach level for selected main commercial fish species in the study area (2009–2019) [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

women. Overall, more men than women were engaged in fishery jobs (Figure S2).

4 | DISCUSSION

The establishment of Bujagali hydropower dam has resulted in a number of modifications to the UVN that include the submerging of Bujagali falls and creation of a 388-ha reservoir (Kabungo, Jalard, & Pal, 2018) as well re-location of the Bujagali falls tourism site and the 84 adjoining homes (Kabungo et al., 2018; Kimbowa &

Mourad, 2019). The reservoir swallowed up the original river banks and part of the surrounding terrestrial environment creating new habitats that could provide opportunities for fish breeding and nursery (Bassa et al., 2021; Nkalubo et al., 2017; Rosenfeld & Todd, 2006). This probably could be the reason for the observed increase in annual fish catch along the UVN over the study period, particularly at the mid-reservoir and upstream, where a huge mukene fishery currently thrives. Total catches for all species combined were lower at the downstream transect, compared with the upstream transects, probably because the downstream transect is more exposed to variable water flows and volumes than upstream sites. In addition, the dam

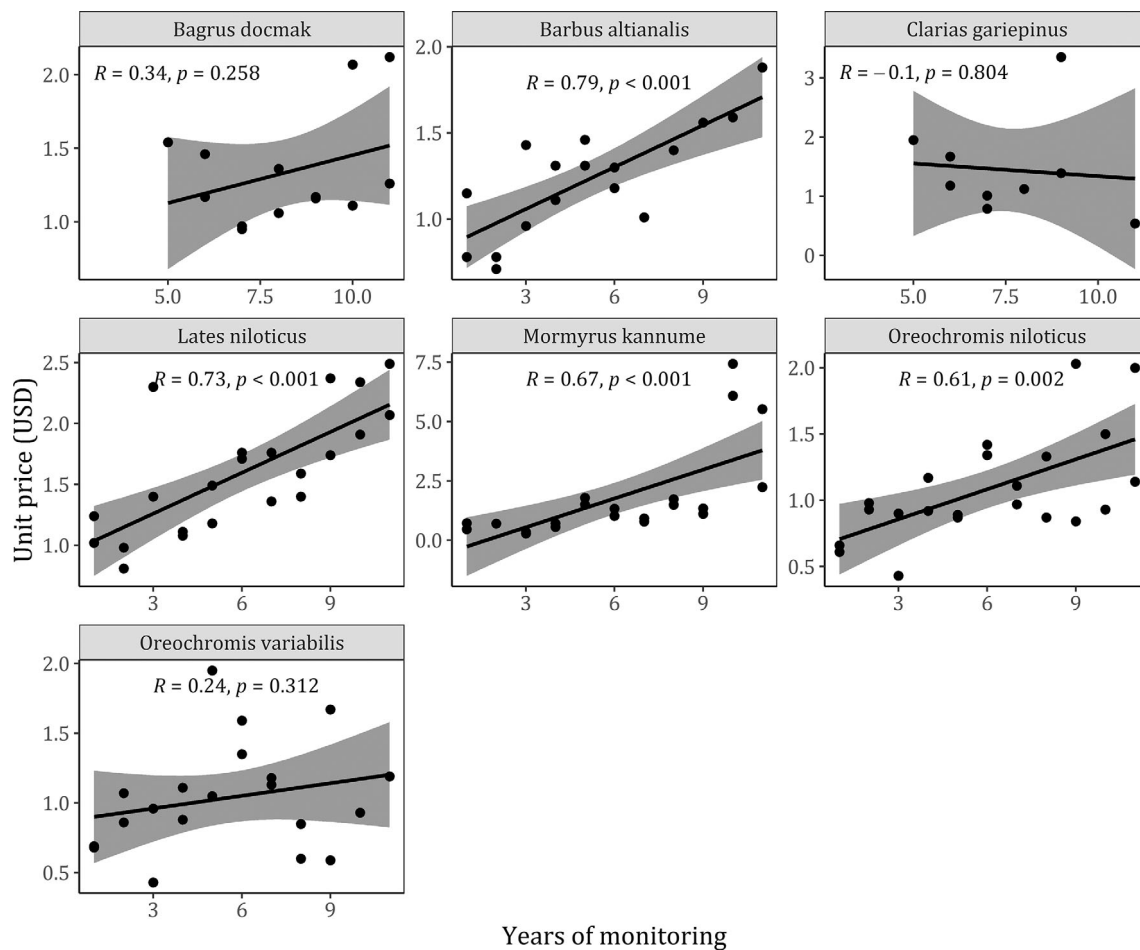


FIGURE 4 Changes in average unit price kg^{-1} of selected main commercial fish species landed at the three study transects from 2009 to 2019

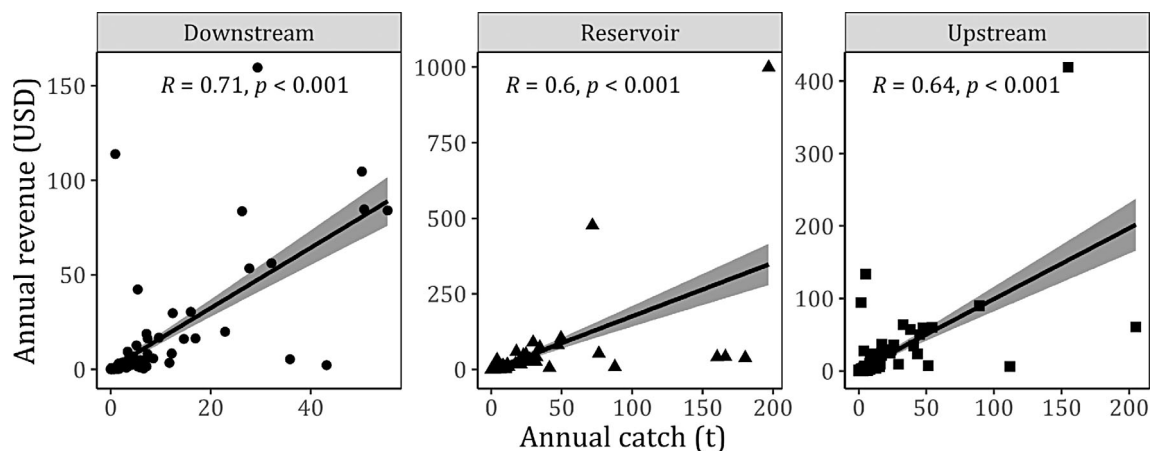


FIGURE 5 Correlation between annual fish catch and beach revenue of catch at the three study transects on UVN

barriers, spillways, and turbines could be disrupting downstream fish movements, constraining the fish feeding regimes, breeding patterns, and recruitment processes, observations that have been documented in other studies (Agostinho, Pelicice, & Gomes, 2008; Levin & Tolimieri, 2001). Between 2009 and 2019, fishing boats increased

from 31 in 2009 to 293 in 2019, whereas fishers rose from 83 to 500. This was possible because the fisheries production could have been sustained by the new habitat conditions in the modified river. In 2014, a maximum annual catch of 461.4 t was attained compared with the lowest of 54.2 t recorded in 2009, attributed to influx and

FIGURE 6 Changes in fishery job categories engaging riverside communities on UVN (2009–2019)

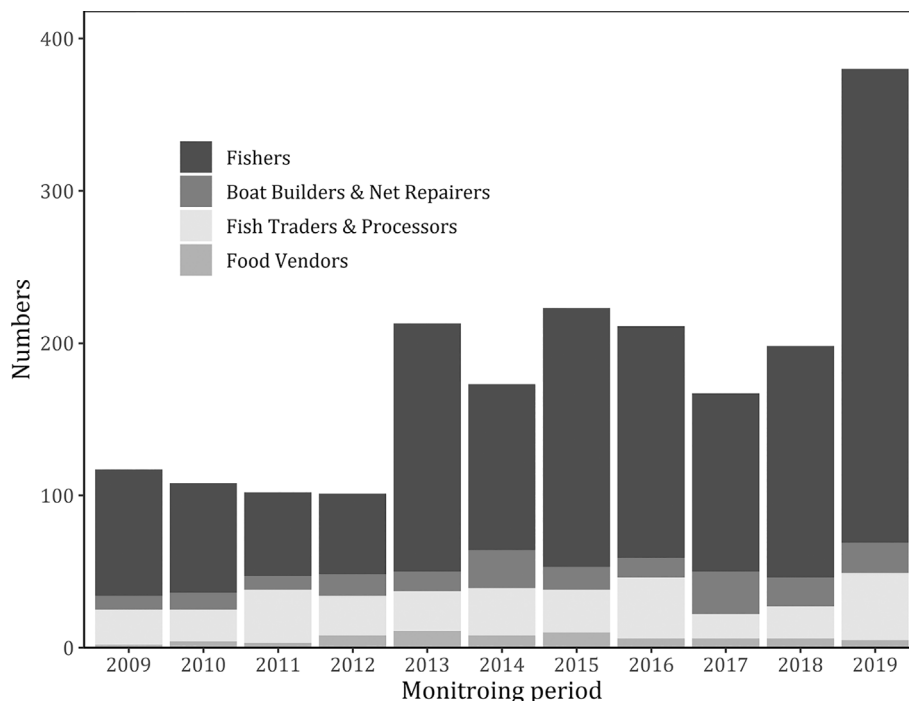


PLATE 2 Selected fishery jobs engaging riverside communities on UVN: fishing boats docked after a fishing trip (a), repair of fishing nets (b); onshore handling and drying of mukene catch (c and e), longline fishing along the riverbanks (d), and repair of a damaged fishing boat (f). Photo taken at Mid-Reservoir by Mr. Nduwayesu Everest in September 2019 [Color figure can be viewed at wileyonlinelibrary.com]

increase of fish species. However, *P. aethiopicus* and *L. victorianus* declined in the commercial catches in the subsequent records, suggesting these fish stocks were negatively impacted by modification of the river. The use of *M. kannume* juveniles as bait for Nile perch fishery encouraged its overfishing even though this corresponded with increased catches from 3.3 t in 2009 to 148.2 t in 2019. Fishing effort and methods for particular fish stock are influenced by fish habitat characteristics and nature of fishery (Geheb et al., 2008; Thomas, Failor, & Thorpe, 2012; Njock and Westlund, 2010; Hovg rd and Lassen, 2000). This is also shown in this study, where the type of fish species

caught, catch per unit of effort (CPUE), and fishing habitat was dependent on the choice of fishing gear.

The critically endangered species *L. victorianus* was occasionally encountered in the commercial catches, mostly from the upstream sites, a further indication that the species are under threat and the need to protect them from getting extinct. The near decimation of these species could have been due to overfishing, habitat alteration, and probably predation pressure from *Lates niloticus* (Nile perch) and interspecific competition by *Oreochromis niloticus* as earlier reported (Chapman et al., 1996; Ogutu-Ohwayo, 1993; Anders Carlson, 2007;

Mbabazi, Ogutu-Ohwayo, Wandera, & Kiziito, 2004; Mwanja, Mwanja, Muwanika, Masembe, & Nyakaana, 2012). The changes in catch composition, and abundance in the commercial catch during the study period could suggest the coupling effects of the hydropower dam activities and ineffective fisheries management. The highest number of species (15 species) was encountered in 2014. The period also coincided with high peaks in catch and beach revenue (Figures 3 and 5). The potamodromous fish species, *L. altianalis*, *M. kannume*, and *L. victorianus* were recovered mostly at the downstream transect. Lentic species such as *L. niloticus*, *O. niloticus*, *P. aethiopicus*, *C. gariepinus*, *O. variabilis*, *B. docmak*, *M. kannume*, and *L. altianalis* were encountered in the reservoir including the upstream site where lake-like conditions were created. Hydropower dams are known to alter the river habitat characteristics, thereby affecting aquatic ecosystem functioning including fish physiological and behavioral performance, fish population, and movements (Grantham & Moyle, 2014; Levin & Tolimieri, 2001). Moreover, hydropower dam barriers are known to adversely affect aquatic biodiversity by causing reduction of species populations and abundance (Jellyman & Harding, 2012; Smokorowski & Pratt, 2007). Such trends are becoming evident with the establishment of Bujagali HP dam. For example, since 2014 on UVN, two fish species, *P. aethiopicus* and *L. victorianus* catches were rare in commercial catches. Prior to construction of Bujagali HP dam, *P. aethiopicus* was abundant from 2009 to 2013. The reservoir conditions could have promoted environmental conditions that favored the riverine fish species to adapt to lentic-like conditions. Other species, *O. leucostictus*, *P. aethiopicus*, *L. victorianus*, were hardly recovered at any of the three transects. It is also possible that the dam could have enhanced fisheries production as evidenced by the drastic increase in fish species and total fish catches recorded in 2014. This rise in total fish production could be attributed to lentic acclimatized species, *L. niloticus*, and *O. niloticus* and *B. docmak* that inhabit pelagic water column with lake-like conditions (Loures & Pompeu, 2019). The reservoir conditions, characterized by enrichment of fish food materials favor the habitat to act as the breeding and nursery areas that support fish reproduction and ecosystem productivity (Agostinho, Pelicice, Petry, Gomes, & Júlio, 2007; Kimbowa & Mourad, 2019; BHP, 2007). Fluctuations in annual catches landed between 2015 and 2018 could be explained by the increased fishing pressure characterized by illegal and undersized fishing gears. For example, fishing on UVNs was dominated by basket traps, cast nets, and monofilaments which are detrimental to fish population through recruitment fishing. These gears are prohibited in Uganda (The Fish [Fishing] Rules, 2010), because they are nonselective, thus crop juveniles and spawning mothers of large-sized species such as *L. niloticus*, tilapias, and *B. docmak* (Rabour, Gichuki & Moreau, 2003; Natugonza, Valtysson, & Jónsson, 2016). However, their prevalence on the river is an indication of weak enforcement and management of the river fisheries. Increase in price per unit kilogram and fish value registered on UVN was attributed to high market demands for fish and fish products which could be due to the growing human population. From 2009 to 2016, *L. niloticus* was the most highly priced fish species with a mean unit price of 2.4 US dollars kg^{-1} among commercial species. The value of fish is influenced

by the species type, fish size, quality, supply, and customers' preferences (Kim, 2003; Matiya, Wakabayashi, Ng, & Takenouchi, 2005; Zhang, Hollowed, Lee, & Kim, 2011). *L. niloticus* is highly demanded at local and international markets (Garcia & Rosenberg, 2010; Pelster & Scheid, 1992), and forms a major fish export commodity for Uganda, fetching US\$ 100,000 from 26,260 t in 2019. This is attributed to its high-quality fillet and the highly prized large swim bladder (fish maw). This demand has resulted in high fishing pressure on the species in the major water bodies of Uganda, including UVN. From 2016 to 2019, *M. kannume* mean price kg^{-1} remarkably increased and was the most highly valued commercial fish species at mean price of US \$ 7.0 kg^{-1} recorded in 2018. The expansion of *M. kannume* bait fishery could be explained by the increasing demand for live juveniles as baits for the Nile perch fishery on lakes Victoria and Kyoga. The large *M. kannume* are also targeted for human food, thus exerting more pressure on their stock. This may result in a total collapse of the fishery if no strategic species-specific management interventions are instituted (Bassa et al., 2020; Bassa et al., 2021). Such management interventions could target reducing fishing efforts and restricting the harvesting gears. Correspondingly, the high beach revenue accrued in 2019 and 2014 was probably due to high catches of both *L. niloticus* and *M. kannume*. From 2014 to 2018, total annual catches and total beach revenue declined, probably due to resource overexploitation by rampant use of illegal fishing gears and methods.

4.1 | Significance of riverine fisheries to the riparian community livelihoods

The riverine fisheries sector plays a vital role in livelihood activities that contribute greatly to national development through food security, fish protein, and employment. New fishing grounds established after completion of Bujagali HP dam offered the riverside community with more fishery jobs, especially at the new fish landing sites. For instance, fishing effort as well as total annual catch and beach revenue increased at the mid-reservoir transect, starting from 2013 onwards. The UVN fisheries have been of economic importance to the fisher folk communities for the past few decades, providing socioeconomic benefits and food for human and animal industry (Jansen & Kugonza, 2019; Kimbowa & Mourad, 2019). As is the case for many fisheries globally (Rahman et al., 2009; Samuel, 2007), fishing was the primary and dominant activity engaging lakeside communities involved along the fisheries value chains on the UVN. Gender roles for men and women in the UVN fisheries were disparate as happens in most fishing communities. This dichotomy of gender roles in the fishery is prescribed by customary beliefs, norms, and cultural settings (Luwa, 2007). Across most fisheries, men mostly participate in fishing and women are engaged in postharvest handling and marketing activities (FAO, 2016; Geheb et al., 2008). While most fishers prioritize income from fishing expeditions, some consider their catch for domestic food (food security and nutrition). In most fisheries, women dominate the post-harvest fish handling activities (Weeratunge, Snyder, & Sze, 2010). The other fishery-related jobs that exclusively engaged

men were boat building and construction/repair of fishing gears. The fishing gear repairers and boat builders were fewer, which could imply that most fishers repaired their boats and gears by themselves to save on costs.

5 | CONCLUSION AND RECOMMENDATIONS

From this study, we conclude that Bujagali HP dam construction has altered the community assemblages of the UVN fisheries, characterized by a decline in commercial catch species composition and increase in fishing effort, annual catches, and catch revenue. The resulting reservoir has promoted a huge fishery of *R. argentea*, while a post-dam construction has led to the emergence of a lucrative bait fishery based on juvenile *M. kannume* downstream of the dam. Further, the study reveals an ecosystem fishing downtrend of the large fish species, which could lead to their stock collapse. Fisheries sustainability on UVN is largely threatened by weak management and non-compliance to the existing fisheries regulations, evidenced by high prevalence of illegal fishing gears, unregulated fishing effort, and catching of juveniles, particularly of Nile perch and *M. kannume*. The *M. kannume* fishery has shown signs of stock decline, thus calling for the immediate ban on fishing of immature fish and use of illegal fishing gears on the UVN. We therefore recommend strengthening enforcement of fisheries regulations by the responsible government departments to curb the illegal unreported and unregulated (IUU) fishing and overexploitation on the UVN and implementation of aquatic biodiversity protection and conservation actions by the management of Bujagali HP dam to mitigate potential threats and impacts to the river biodiversity.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in Dryad at <https://doi.org/10.5061/dryad.kwh70rz61>.

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REFERENCES

Adams, W. M. (1985). The downstream impacts of dam construction: A case study from Nigeria. *Transactions of the Institute of British Geographers*, 10, 292. <https://doi.org/10.2307/622179>

- Agostinho, A. A., Pelicice, F. M., & Gomes, L. C. (2008). Dams and the fish fauna of the Neotropical region: Impacts and management related to diversity and fisheries. *Brazilian Journal of Biology*, 68, 1119–1132. <https://doi.org/10.1590/S1519-69842008000500019>
- Agostinho, A. A., Pelicice, F. M., Petry, A. C., Gomes, L. C., & Júlio, H. F. (2007). Fish diversity in the upper Paraná River basin: Habitats, fisheries, management and conservation. *Aquatic Ecosystem Health & Management*, 10, 174–186. <https://doi.org/10.1080/14634980701341719>
- Arantes, C. C., Fitzgerald, D. B., Hoeinghaus, D. J., & Winemiller, K. O. (2019). Impacts of hydroelectric dams on fishes and fisheries in tropical rivers through the lens of functional traits. *Current Opinion in Environment Sustainability*, 37, 28–40. <https://doi.org/10.1016/j.cosust.2019.04.009>
- Araújo, E. S., Marques, E. E., Freitas, I. S., Neuberger, A. L., Fernandes, R., & Pelicice, F. M. (2013). Changes in distance decay relationships after river regulation: Similarity among fish assemblages in a large Amazonian river. *Ecology of Freshwater Fish*, 22, 543–552. <https://doi.org/10.1111/eff.12054>
- Arthur, R. C., Infante, D. M., Daniel, W. M., Wehrly, K. E., Wang, L., & Brenden Travis, O. (2017). Assessment of dam effects on streams and fish assemblages of the conterminous USA. *Science of the Total Environment*, 586, 879–889. <https://doi.org/10.1016/j.scitotenv.2017.02.067>
- Barthem, R. B., de Brito Ribeiro, M. C. L., & Petrere, M. (1991). Life strategies of some long-distance migratory catfish in relation to hydroelectric dams in the Amazon Basin. *Biological Conservation*, 55, 339–345. [https://doi.org/10.1016/0006-3207\(91\)90037-A](https://doi.org/10.1016/0006-3207(91)90037-A)
- Bassa, S., Getabu, A., Ogello, E., Taabu Munyaho, A., Oteino Owiti, D., Nakiyende, H., ... Nkalubo, W. (2021). Stock assessment of *Lates niloticus* in upper Victoria Nile and its impact on Uganda's economy. *Uganda Journal of Agricultural Sciences*, 19, 11–26. <https://doi.org/10.4314/ujas.v19i2.2>
- Bassa, S., Oteino Owiti, D., Ogello, E., Getabu, A., Muhoozi, L. I., Nakiyende, H., ... Olwa, R. (2020). Ecosystem integrity of the upper Victoria Nile in East Africa based on habitat and fish species biotic indices. *Uganda Journal of Agricultural Sciences*, 19, 33–49. <https://doi.org/10.4314/ujas.v19i1.4>
- BHP. (2007). Environmental and social impact monitoring of the Bujagali hydropower project (BHPP), Uganda fisheries component monthly patterns in physicochemical conditions and fish catch in the immediate vicinity of the Bujagali hydropower construction site.
- Carlson, A., 2007. Micro- and macro-algae: Utility for industrial applications, Outputs from the EPOBIO project CNAP University of York York UK. <https://doi.org/10.1037/11474-008>
- Chapman, L. J., Chapman, C. A., Kaufman, L., Witte, F., & Balirwa, J. (2008). Biodiversity conservation in African inland waters: Lessons of the Lake Victoria region. *Verhandlungen des Internationalen Verein Limnologie*, 30, 16–34. <https://doi.org/10.1080/03680770.2008.11902077>
- Chapman, L. J., Chapman, C. A., Ogutu-Ohwayo, R., Chandler, M., Kaufman, L., & Keiter, A. E. (1996). Refugia for endangered fishes from an introduced predator in Lake Nabugabo, Uganda. *Conservation Biology*, 10, 554–561. <https://doi.org/10.1046/j.1523-1739.1996.10020554.x>
- da Silva Junior, O. M., dos Santos, M. A., Szlafsztein, C. F., Gomez, J. M. A., & Pereira, J. P. (2018). Protected areas as strategies for preserving vegetation cover in the vicinity of hydroelectric projects in the Brazilian Amazon. *Energy, Sustainability and Society*, 8, 1–16. <https://doi.org/10.1186/s13705-018-0172-1>
- FAO. (2016). *The state of world fisheries and aquaculture. Contributing to food security and nutrition for all* (p. 200). Rome: FAO 92-5-105177-1.
- Farrington, D. P. (1991). Longitudinal research strategies: Advantages, problems, and prospects. *Journal of the American Academy of Child & Adolescent Psychiatry*, 30(3), 369–374.
- Forsberg, B. R., Melack, J. M., Dunne, T., Barthem, R. B., Goulding, M., Paiva, R. C. D., ... Weisser, S. (2017). The potential impact of new

- Andean dams on Amazon fluvial ecosystems. *PLoS One*, 12(8), 1–35. <https://doi.org/10.1371/journal.pone.0182254>
- Garcia, S. M., & Rosenberg, A. A. (2010). Food security and marine capture fisheries: Characteristics, trends, drivers and future perspectives. *Philosophical Transactions of the Royal Society B*, 365, 2869–2880. <https://doi.org/10.1098/rstb.2010.0171>
- Geheb, K., Kalloch, S., Medard, M., Nyapendi, A. T., Lwenya, C., & Kyangwa, M. (2008). Nile perch and the hungry of Lake Victoria: Gender, status and food in an east African fishery. *Food Policy*, 33, 85–98. <https://doi.org/10.1016/j.foodpol.2007.06.001>
- Grantham, T. E., & Moyle, P. B. (2014). Assessing flows for fish below dams: A systematic approach to evaluate compliance of California's dams with Fish and Game Code Section 5937. Center for Watershed Sciences Technical Report (CWS-2014-01), University of California, Davis. p. 106.
- Greenwood, P. H. (1976). Fish Fauna of the Nile. In Rózsa, J. (Ed.), *The Nile, Biology of an Ancient River. Monographiae Biologicae*, Vol. 1. Dordrecht: Springer. https://doi.org/10.1007/978-94-010-1563-9_18
- Hoeinghaus, D. J., Agostinho, A. A., Gomes, L. C., Pelicice, F. M., Okada, E. K., Latini, J. D., ... Winemiller, K. O. (2009). Effects of river impoundment on ecosystem services of large tropical rivers: Embodied energy and market value of artisanal fisheries. *Conservation Biology*, 23, 1222–1231. <https://doi.org/10.1111/j.1523-1739.2009.01248.x>
- Hovgård, H., & Lassen, H. (2000). *Manual on estimation of selectivity for gillnet and longline gears in abundance surveys* (FAO Fisheries Technical Paper 397, Rome).
- Hughes, F. M. R. (1984). A comment on the impact of development schemes on the floodplain forests of the Tana River of Kenya The Royal Geographical Society (with the Institute of British Geographers). *The Geographical Journal*, 150, 230–244.
- Jansen, P., & Kugonza, R. (2019). “Like fish on land”: The impacts of hydroelectric power projects on resettled communities in Uganda and Laos. Amsterdam, The Netherlands. <https://www.bothends.org/en/Whats-new/Publicaties/Like-Fish-on-Land-The-impacts-of-hydroelectric-power-projects-on-resettled-communities-in-Uganda-and-Laos/>
- Jellyman, P. G., & Harding, J. S. (2012). The role of dams in altering freshwater fish communities in New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 46, 475–489. <https://doi.org/10.1080/00288330.2012.708664>
- Kabungu, A., Jalard, M., & Pal, M. (2018). *Bujagali environmental and social impact assessment summary* (pp. 1–14). Kampala, Uganda. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Environmental-and-Social-Assessments/Uganda_-_Bujagali_Energy_Limited_-_ESIA_Summary.pdf
- Kim, S. (2003). Jeju Island women divers' association in South Korea: A source of social capital. *Asian Journal of Women's Studies*, 9, 37–39. <https://doi.org/10.1080/12259276.2003.11665942>
- Kimbowa, G., & Mourad, K. A. (2019). Assessing the Bujagali Hydropower Project in Uganda. *Modern Approaches in Oceanography and Petrochemical Sciences*, 2, 157–168. <https://doi.org/10.32474/MAOPS.2019.02.000141>
- Levin, P. S., & Tolimieri, N. (2001). Differences in the impacts of dams on the dynamics of salmon populations. *Animal Conservation*, 4, 291–299. <https://doi.org/10.1017/S1367943001001342>
- Loures, R. C., & Pompeu, P. S. (2019). Temporal changes in fish diversity in lotic and lentic environments along a reservoir cascade. *Freshwater Biology*, 64(10), 1806–1820.
- Luwa, K. J., 2007. Power and Development: Controversies over the Bujagali Hydropower Project along the Nile River in Uganda, 60.
- LVFO. (2005). *Catch assessment survey, standard operating procedures*, No. 1. Jinja, Uganda: LVFO.
- LVFO. (2014). *East African community the standard operating procedures for catch fisheries frame surveys*. Uganda: Jinja.
- Marmulla, G. (2001). Dams, fish and fisheries. Opportunities, challenges and conflict resolution. In *FAO fisheries technical paper*, No. 419 166p. Rome: FAO.
- Matiya, G., Wakabayashi, Y., Ng, D., & Takenouchi, N. (2005). A logit analysis of socio-economic factors influencing people to become fisherman around Lake Malombe in Malawi. *Journal of Applied Sciences Research*, 1, 18–23.
- Mbabazi, D., Ogutu-Ohwayo, R., Wandera, S. B., & Kiziito, Y. (2004). Fish species and trophic diversity of haplochromine cichlids in the Kyoga satellite lakes (Uganda). *African Journal of Ecology*, 42, 59–68. <https://doi.org/10.1111/j.0141-6707.2004.00492.x>
- Mishra, L. (2016). Focus group discussion in qualitative research. *Techno-Learn An International Journal of Educational Technology*, 6, 1. <https://doi.org/10.5958/2249-5223.2016.00001.2>
- Mwanja, M. T., Mwanja, W. W., Muwanika, V., Masembe, C., & Nyakaana, S. (2012). Genetic evidence of successful establishment of the Nile perch (*Lates spp. L.*) in east African lakes and implications for management. *Management of Biological Invasions*, 3, 77–88. <https://doi.org/10.3391/mbi.2012.3.2.02>
- NaFIRRI. (2017). *Characterization of habitats and haplochromine diversity to guide conservation of biodiversity amidst hydropower developments along the upper Victoria Nile*, No. 1. Jinja, Uganda: NaFIRRI.
- NAPE. (2007). *The unresolved issues in the Bujagali dam project in Uganda*. Kampala Uganda: A lack of transparency and public participation.
- Natugonza, V., Valtysson, H. T., & Jónsson, S. (2016). *Improving fisheries management strategies for Lake Victoria by means of ecological modelling optimization*. Akureyri, Iceland: United Nations University.
- Nelson, T. C., Doukakakis, P., Lindley, S. T., Schreier, A. D., Hightower, J. E., Hildebrand, L. R., ... Webb, M. A. H. (2013). Research tools to investigate movements, migrations, and life history of sturgeons (Acipenseridae), with an emphasis on marine-oriented populations. *PLoS One*, 8, e71552. <https://doi.org/10.1371/journal.pone.0071552>
- Njock, J.-C., & Westlund, L. (2010). Migration, resource management and global change: Experiences from fishing communities in West and Central Africa. *Marine Policy*, 34(4), 752–760. <https://doi.org/10.1016/j.marpol.2010.01.020>
- Nkalubo, W., Balirwa, J., Bassa, S., Muhumuza, E., Monic, N., & Mangeni, R. (2017). Fish breeding areas as a management tool for fisheries resources in Lake Victoria, East Africa. *African Journal of Tropical Hydrobiology and Fisheries*, 15, 15–24.
- Northcote, T. G. (1998). Migratory behaviour of fish and its significance to movement through riverine fish passage facilities. In M. Jungwirth, S. Schmoltz, & S. Weiss (Eds.), *Fish migration and fish bypasses* (pp. 3–18). Vienna, Austria: Fishing News Books.
- Ogutu-Ohwayo, R. (1988). Reproductive potential of the Nile perch, *Lates niloticus* L. and the establishment of the species in lakes Kyoga and Victoria (East Africa). *Hydrobiologia*, 162, 193–200. <https://doi.org/10.1007/BF00016667>
- Ogutu-Ohwayo, R. (1993). The effects of predation by Nile Perch, *Lates niloticus* L., with suggestions for conservation of endangered endemic cichlids. *Conservation Biology*, 7, 701–711. <https://doi.org/10.1046/j.1523-1739.1993.07030701.x>
- Pelster, B., & Scheid, P. (1992). Countercurrent concentration and gas secretion in the fish swim bladder. *Physiological Zoology*, 65, 1–16. <https://doi.org/10.1086/physzool.65.1.30158236>
- Pringle, C. M., Freeman, M. C., & Freeman, B. J. (2000). Regional effects of hydrologic alterations on riverine macrobiota in the New World: Tropical-temperate comparisons. *Bioscience*, 50, 807–823. [https://doi.org/10.1641/0006-3568\(2000\)050\[0807:REOHAO\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2000)050[0807:REOHAO]2.0.CO;2)
- R Core Team (2021). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. <https://www.R-project.org/>
- R J Burnside International Limited (2006). *Bujagali energy limited Bujagali hydropower project social and environmental assessment Main report* (p. 58). Guelph, Canada: R J Burnside International Limited.
- Rabour, C. O., Gichuki, J., & Moreau, J. (2003). Growth, mortality and recruitment of Nile perch *Lates niloticus* (L. Centropomidae) in the Nyanza Gulf of Lake Victoria: an evaluation update. *NAGA, WorldFish Center Quarterly*, 26(4), 8–12.

- Rahman, M. M., Hossain, M. M., Rahman, S. M., Alam, M. H., Resource, M., Discipline, T., ... Project, D. (2009). Fish marketing system in Khulna, Bangladesh. *Journal of Innovation and Development Strategy*, 3, 27–31.
- Rosenfeld, J. S., & Todd, H. (2006). Information needs for assessing critical habitat of freshwater fish. *Canadian Journal of Fisheries and Aquatic Sciences*, 63, 683–698. <https://doi.org/10.1139/f05-242>
- Rytwinski, T., Algera, D. A., Taylor, J. J., Smokorowski, K. E., Bennett, J. R., Harrison, P. M., & Cooke, S. J. (2017). What are the consequences of fish entrainment and impingement associated with hydroelectric dams on fish productivity? A systematic review protocol. *Environmental Evidence*, 6, 1–9. <https://doi.org/10.1186/s13750-017-0087-x>
- Samuel, L. (2007). Women, work and fishing: An examination of the lives of fisherwomen in Kerala. *South Asia Research*, 27, 205–227. <https://doi.org/10.1177/026272800702700205>
- Smokorowski, K. E., & Pratt, T. C. (2007). Effect of a change in physical structure and cover on fish and fish habitat in freshwater ecosystems—A review and meta-analysis. *Environmental Reviews*, 15, 15–41. <https://doi.org/10.1139/a06-007>
- Stickler, C. M., Coe, M. T., Costa, M. H., Nepstad, D. C., McGrath, D. G., Dias, L. C. P., ... Soares-Filho, B. S. (2013). Dependence of hydropower energy generation on forests in the Amazon Basin at local and regional scales. *Proceedings of the National Academy of Sciences of the United States of America*, 110, 9601–9606. <https://doi.org/10.1073/pnas.1215331110>
- The Fish(Fishing) Rules. (2010). Statutory Instruments No. 33.
- The World Bank. (2018). Implementation completion and results report (Ida guarantee No. B0130) on an international development association partial risk guarantee in the amount of up to us\$115 million to the Republic of Uganda for a private power generation (Bujagali) Project. In *Energy and Extractives Global Practice* (p. 49). Kampala, Uganda: The World Bank. <https://documents1.worldbank.org/curated/en/546131539715898602/pdf/Bujagali-ICR-Report-10102018.pdf>
- Thieme, M. L., Tickner, D., Grill, G., Carvallo, J. P., Goichot, M., Hartmann, J., ... Opperman, J. (2021). Navigating trade-offs between dams and river conservation. *Global Sustainability*, 4, 1–7. <https://doi.org/10.1017/sus.2021.15>
- Thomas, B., Failler, P., & Thorpe, A. (2012). Migration of Senegalese fishers: A case for regional approach to management. *Maritime Studies*, 11, 1–14. <https://doi.org/10.1186/2212-9790-11-1>
- Vörösmarty, C. J., McIntyre, P. B., Gessner, M. O., Dudgeon, D., Prusevich, A., Green, P., ... Davies, P. M. (2010). Global threats to human water security and river biodiversity. *Nature*, 467, 555–561. <https://doi.org/10.1038/nature09440>
- Weeratunge, N., Snyder, K.A., Sze, C.P., 2010. Gleaner, fisher, trader, processor: Understanding gendered employment in fisheries and aquaculture. *Fish and Fisheries*, 11(4), 405–420. <https://doi.org/10.1111/j.1467-2979.2010.00368.x>
- White, G. F. (1988). The environmental effects of the high dam at Aswan. *Environment*, 30, 5–40. <https://doi.org/10.1080/00139157.1988.9930898>
- Wilmsen, B., & van Hulten, A. (2017). Following resettled people over time: The value of longitudinal data collection for understanding the livelihood impacts of the three gorges dam, China for understanding the livelihood impacts of the three gorges dam, China. *Impact Assessment and Project Appraisal*, 35, 94–105. <https://doi.org/10.1080/14615517.2016.1271542>
- Winemiller, K. O., McIntyre, P. B., Castello, L., Fluet-Chouinard, E., Giarrizzo, T., Nam, S., ... Sáenz, L. (2016). Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. *Science* (80-), 351, 128–129. <https://doi.org/10.1126/science.aac7082>
- Witte, F., Goldschmidt, T., Wanink, J., van Oijen, M., Goudswaard, K., & Witte-maas, E. (1992). The destruction of an endemic species flock: Quantitative data on the decline of the haplochromine cichlids of Lake Victoria. *Environmental Biology of Fishes*, 34(1), 1–28. <https://doi.org/10.1007/BF00004782>
- Witte, F., Kische-Machumu, M. A., Mkumbo, O. C., Wanink, J. H., Goudswaard, P. C., van Rijssel, J. C., Lake, V. (2008). The fish Fauna of Lake Victoria during a century of human induced perturbations. In J. Snoeks & A. Getahun (Ed.), *Proceedings of the Fourth International Conference on African Fish and Fisheries*, Addis Ababa, Ethiopia (pp. 49–66). Tervuren: Royal Museum Central Africa.
- Zhang, C. I., Hollowed, A. B., Lee, J.-B., & Kim, D.-H. (2011). An IFRAME approach for assessing impacts of climate change on fisheries. *ICES Journal of Marine Science*, 68, 1318–1328. <https://doi.org/10.1093/icesjms/fsr073>
- Ziv, G., Baran, E., Nam, S., Rodríguez-Iturbe, I., & Levin, S. A. (2012). Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. *Proceedings of the National Academy of Sciences of the United States of America*, 109, 5609–5614. <https://doi.org/10.1073/pnas.1201423109>

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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